3.5 On-Board Noise Jamming Sensitivity Analysis

The intent of on-board noise jamming is to mask the true target signal such that the target position is unknown or uncertain. Typically, on-board noise jamming has one of two forms: barrage noise jamming or spot noise. Barrage noise essentially consists of continuous random amplitude- and frequency-modulated signals over a broad frequency band covering the operating frequencies of one or several victim radar types. Spot noise is more selective, consisting of random amplitude- and frequency-modulated signals over a narrow frequency band covering the expected operating frequencies of a single radar type.

On-board noise jamming is differentiated from off-board and stand-off jamming by the location of the jammer, which is carried on the target aircraft rather than on a support vehicle platform. An important operational feature of the on-board jammer is that the jammer is always in the victim radar's main beam, while off-board jammers are usually positioned in the antenna sidelobes of the victim radar.

The essential criterion for noise jammer effectiveness is the target burn-through range; i.e., the range at which the target/jammer signal ratio (S/J) exceeds a level at which the target can be distinguished from the noise. Burn-through is assumed to occur at the radar receiver signal-to-noise (S/N) detection threshold, which is a function of the probability of detection and the probability of false alarm, a unique value for each radar type.

On-board noise jamming is typically modeled as a "pink noise" source (i.e., band-limited white noise), having a defined average transmitted power level, center frequency, bandwidth, and antenna gain parameters. The one-way propagation loss from the target aircraft to the victim radar is computed to determine the jammer power level at the radar. The effective jammer noise power is assumed to be the average power at the radar, reduced by the ratio of the radar noise bandwidth to the jammer's bandwidth. The calculated target signal return is compared to the sum of the jammer noise plus internal receiver noise to determine if target signal burn-through has occurred.

In ALARM, on-board noise jamming is modeled as a noise source at the target location, having user-defined bandwidth, average power, and center frequency. The jammer antenna is modeled as an omni-directional antenna having a user-specified maximum antenna gain in all directions. One-way jammer propagation losses for both radiation and atmospheric attenuation are computed. It is assumed that noise jammer propagation is not affected by multipath and diffraction. Given that the jammer propagation function is validly modeled, the greatest uncertainties to be evaluated are the burn-through detection threshold and the assumption of an omni-directional jammer antenna.

3.5.1 Objectives and Procedures

The objective of the sensitivity analysis at the function level is to detemine the impact on the jammer signal received at the victim radar due to the on-board jammer antenna gain pattern. At the model level, the objective of the sensitivity analysis is to assess changes in target burn-through range as a function of jammer antenna gain pattern and burn-through detection threshold.

The measure of effectiveness (MOE) used to determine sensitivity at the function level is a 3 dBm difference in mean jammer power, when comparing the test cases with the baseline case. At the model level, the MOE is a 5% difference in normalized mean detection range, when comparing the test cases with the baseline cases.

The procedure to compare the differences in received jammer power and burn-through range as functions of antenna gain pattern is to modify ALARM to include a (sine $(x)/x)^2$ jammer antenna gain function, with the antenna boresight at a fixed position (0.0^0 azimuth and 15.0^0 depression angle) relative to the target aircraft velocity axis. ALARM is run in Contour Plot mode, first with an omni-directional jammer antenna pattern and next with the shaped gain jammer antenna pattern. The modification of ALARM further includes the ability to record the jammer power received at the radar.

The procedure to assess the impact of burn-through detection threshold on target burn-through range is to vary the detection threshold by +4.0 dB in 1.0 dB steps relative to the ALARM-computed detection threshold (variable CONTOR). ALARM is run in Contour Plot mode, with an on-board jammer, at the varied detection thresholds; target burn-through range is recorded for each target offset for each detection threshold.

Table 3.5-1 identifies the specific parameters varied for these sensitivity analyses.

Table 3.5-1 ALARM Runs for On-Board Noise Jamming Sensitivity Analyses

Sensitivity Parameter	Analysis Level	Input Variable	Range of Variation	Output Variable	Test Case Description
Jammer Antenna Gain Pattern	FE and Model	On-board Jammer Antenna Pattern	**Omni-directional antenna pattern**; $(\sin (x)/x)^2$ antenna pattern	Received Jammer Signal; SIGTOI	Modify ALARM to allow user-specified on-board noise jammer antenna patterns. Run ALARM in Contour Plot mode using the two different jammer antenna patterns oriented along the axis of flight of the target aircraft and depressed 15˚ from the horizontal; jammer power= 1 kw; jammer bandwidth= 2*that of victim radar; jammer center frequency matches the victim radar; target altitude= 500 ft; radar frequency= 15 GHz. Record output jammer signal and initial detection range for each offset for both antenna patterns.

Table 3.5-1 ALARM Runs for On-Board Noise Jamming Sensitivity Analyses

Sensitivity Parameter	Analysis Level	Input Variable	Range of Variation	Output Variable	Test Case Description
Burn-Through Detection Threshold	Model	CONTOR	**CONTOR** CONTOR + 1.0DB CONTOR + 2.0DB CONTOR + 3.0DB CONTOR + 4.0DB	SIGTOI	Modify ALARM to allow user-specified increments to the calculated threshold (variable CONTOR). Run ALARM in Contour Plot mode, using five different detection threshold values; baseline ALARM omni-directional jammer antenna pattern; jammer power= 1 kw; jammer bandwidth= 2*that of victim radar; jammer center frequency matches the victim radar; target altitude= 500 ft; radar frequency= 15 GHz. Determine initial detection range for each offset for each threshold.
Note: Values in **bold** indicate baseline cases.					

3.5.2 Results

Figure 3.5-1, two plots of flight path point vs. received jammer power as a function of antenna gain, shows large variation in jammer power received. The jammer signal received for the case of a non-directional antenna always exceeds the jammer signal received for the case of a directional jammer antenna. Since the flight path is offset from the radar, jammer radiation is through the jammer antenna sidelobes rather than the main beam for most target positions along the flight path. Thus, the radiated power is less than that when using the omni-directional antenna (having the main beam gain in all directions or an assumed perfectly pointed jammer antenna). The differential in jammer power is greater than 3 dBm for all points along the flight path, exceeding the MOE significance criteria.

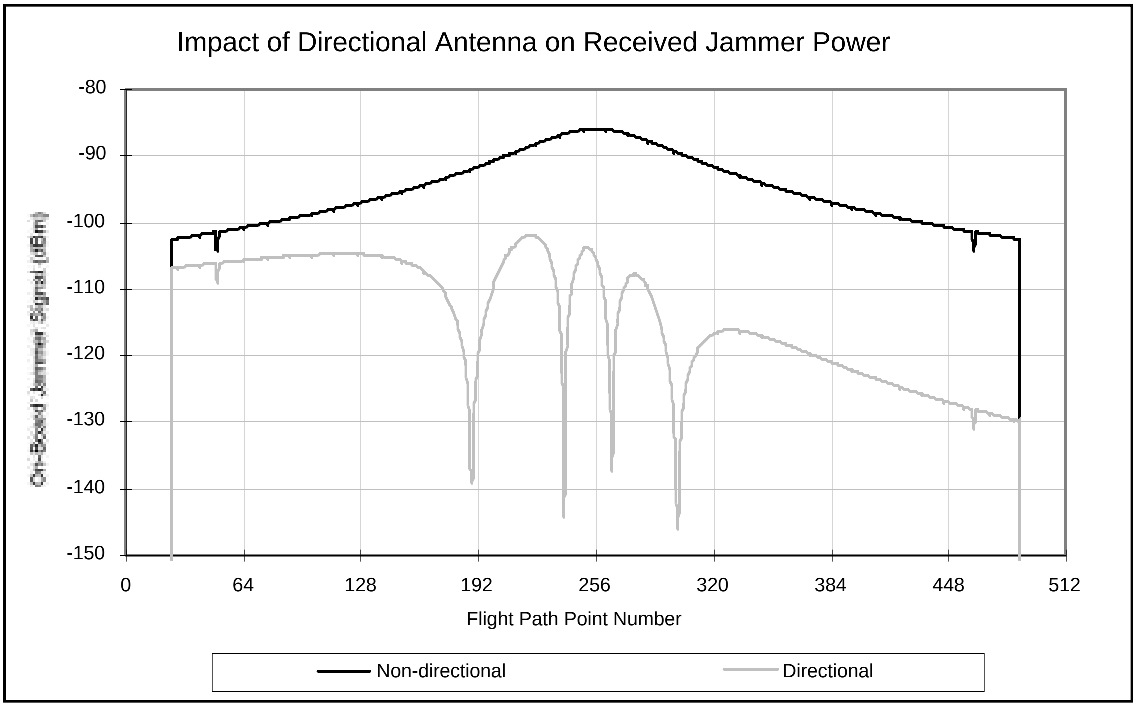

Figure 3.5-1 Impact of Directional Antenna on Received Jammer Power

Figure 3.5-2 shows two plots of target detection range vs. target offset as a function of jammer antenna gain. As can be observed, the effectiveness of the jammer having an omni-directional antenna is better than that of the jammer having a directional antenna gain, so that target burn-through generally occurs at shorter ranges. Table 3.5-2 shows that the difference in the mean normalized detection range is 9.67%, exceeding the acceptance threshold.

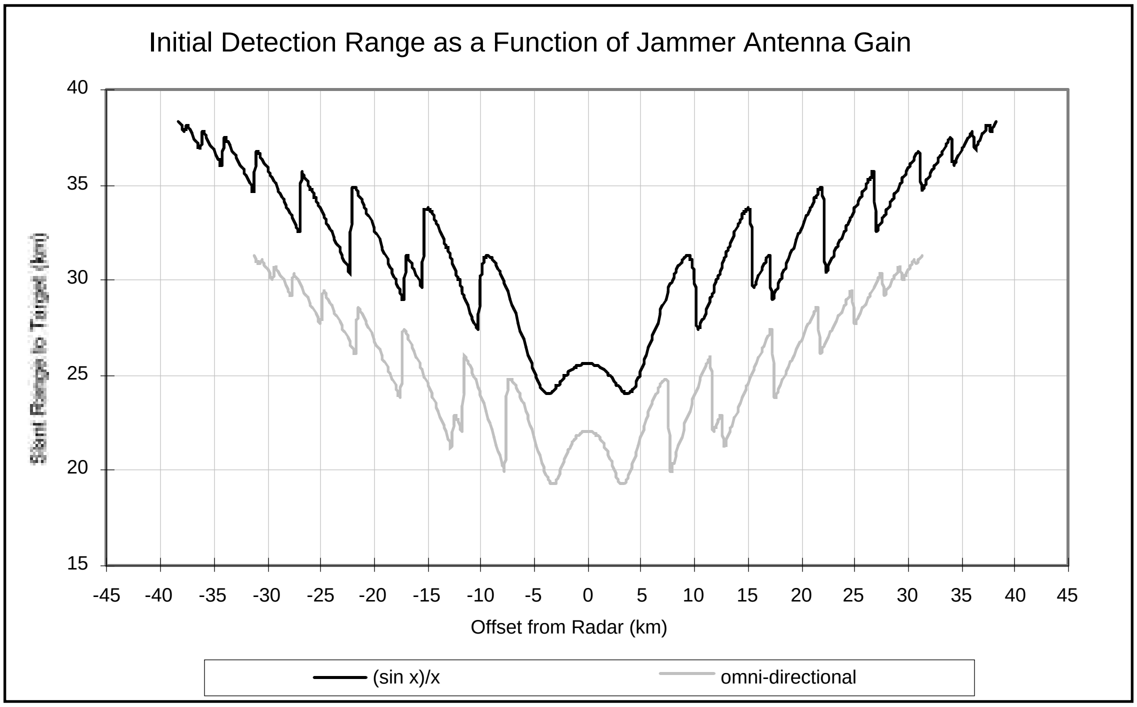

Figure 3.5-2 Initial Detection Range as a Function of Jammer Antenna Gain

Table 3.5-2 Statistics for Detection Range as a Function of Jammer Antenna Gain

Antenna Pattern	Mean (m)	σ (m)	Normalized Mean Difference	% Change
omni-directional (baseline)	25.26	3.38	-	-
(sin x)/x	30.67	4.00	0.05	9.67

The impact of the target burn-through threshold on target detection is illustrated in figure 3.5-3, a family of plots of target burn-through range vs. target offset as a function of the S/J detection threshold. The differences in target detection range appear significant, and are confirmed in table 3.5-3 which indicates a -6.19% difference in the mean normalized detection range for a 1.0 dB difference in the burn-through threshold, exceeding the acceptance criteria.

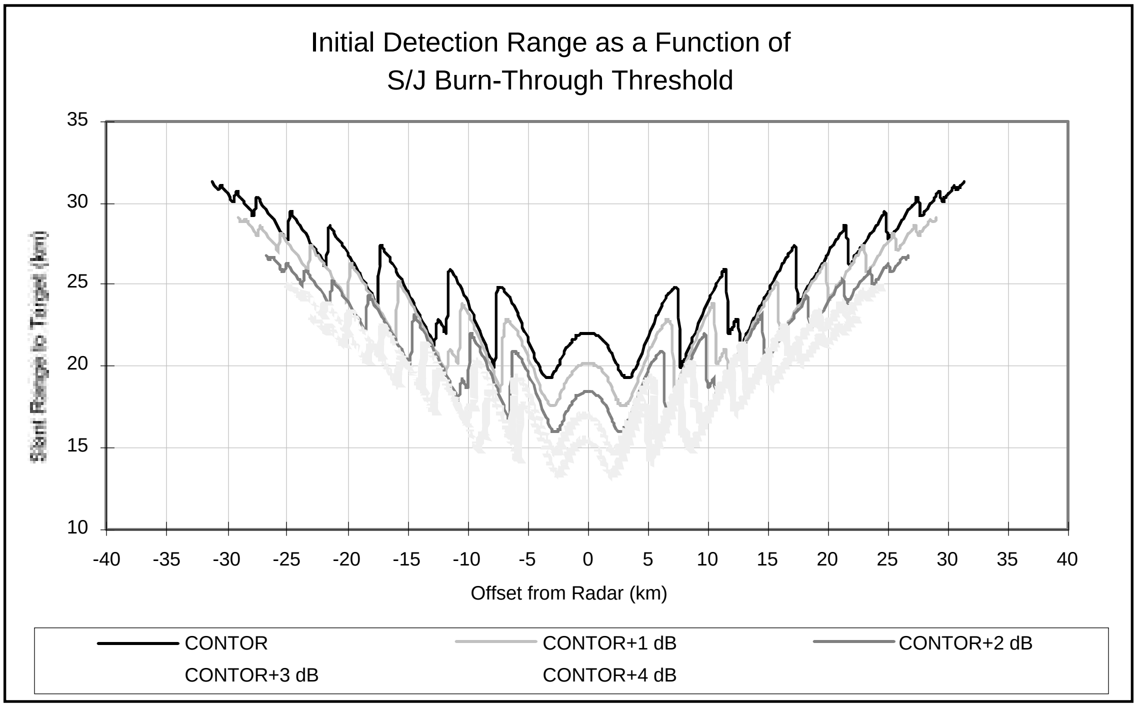

Figure 3.5-3 Target Burn-Through Range as a Function of S/J Burn-Through Threshold

Table 3.5-3 Statistics for Detection Range as a Function of S/J Burn-Through Threshold

Threshold	Mean (m)	σ (m)	Normalized Mean Difference	% Change
CONTOR (baseline)	25.26	3.38	-	-
CONTOR + 1 dB	23.30	3.22	-0.03	-6.19
CONTOR + 2 dB	21.42	3.05	-0.07	-12.27
CONTOR + 3 dB	19.68	2.88	-0.10	-18.27
CONTOR + 4 dB	17.97	2.71	-0.14	-24.14

The analyses indicate that when validating the on-board jamming function it will be essential to measure the jammer antenna gain, its attitude relative to the aircraft center line, and the attitude of the aircraft relative to the radar coordinates, as well as the transmit jammer power and received jammer power. Further, the S/J ratio at target burn-through must be evaluated.

3.5.3 Conclusions

The sensitivity of the burn-through detection threshold on target detectability in the presence of on-board jamming has been shown to be significant. To validate this functional element, it is apparent that the signal-to-jamming threshold at target burn-through should be measured to an accuracy of less than 1.0 dB. This is a significant finding in that the variability between operators, radar display settings, and jammer noise modulation parameters may result in a burn-through threshold variability of greater than the 1.0 dB measurement requirement.

The sensitivity analyses have indicated that the effectiveness of on-board jamming is significantly impacted by the directionality of the jammer antenna. The model user should be aware that the omission of a fixed-position directional antenna in ALARM may lead to significant errors in predicting jammer effectiveness.